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COMPARISON UNDER TWO CONDITIONS

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ABSTRACT In order to understand GPS time comparison characteristics associated with influences from SA (Selective Availability) effects, a number of experiments were carried out in early 1992. The data sampling time associated with the experiments was 10 seconds. Satellite tracking time was 1 hour. The results of frequency spectrum analysis clearly show that: 1) Under normal conditions, GPS time comparison spectrum characteristics are basically level. There are no clear periodic phenomena. Noise processes are phase modulated white noise. 2) When GPS time comparisons are influenced by SA effects, low frequency spectra are relatively clearer. There are obvious periodic phenomena. Among these, 5-15 minute period signals account for approximately 77%. This is nothing else than the cause which leads to obvious drops in GPS time comparison precision.

KEY WORDS Global positioning system Time comparison  
Selective availability Spectrum characteristic

## 1 INTRODUCTION

Since November 15th 1991, the majority of BLOCK II satellites have turned from normal conditions to SA configuration operations. BLOCK I satellites operate under normal conditions from beginning to end. SA (selective availability) conditions are a number of parameters added into random modulation with regard to signal characteristics. How about GPS time comparisons influenced by SA effects with respect to characteristics? This is a particular concern for GPS time transmission users. The reason is that the accuracy and precision of GPS time comparisons influenced by SA both drop to different degrees. There are some results which fall relatively greatly. This will severely influence long range GPS time synchronicity results. For this reason, comparisons and analyses are carried out from received data with regard to the results associated with the two conditions. In conjunction with this, thinking up ways to reduce the influences of SA effects has already turned into an important topic associated with GPS time transmissions.

For the sake of comparing GPS time comparison results under the two types of conditions, we carried out a series of test measurements and analyses in early 1992. Variances associated with time domain characteristic analyses clearly showed that GPS time comparison accuracies influenced by SA effects (use was made of received data for which the sampling period was 10 seconds within a tracking period of 13 minutes) dropped 5-10 fold as compared to the results for normal conditions. This article primarily describes analysis results for a number of frequency domains associated with GPS time comparisons under the two types of conditions. From these, it is possible to know a number of characteristics and patterns of SA effects influencing GPS time comparison frequency domain characteristics.

## 2 FREQUENCY DOMAIN CHARACTERISTIC ANALYSIS

Fig.1 is an example of changes in time difference measurement values associated with GPS time comparisons under the two conditions. In Fig.1, comparison signals are [UTC(SO)-GPS(PRN J)] (J is the satellite PRN serial no.). Data sampling periods are 10 seconds. Satellite tracking periods are 1 hour. The situation associated with BLOCK I satellites is similar to the situation associated with PRN 3 in Fig.'s. Amplitude fluctuations are not great. The case associated with BLOCK II satellites influenced by SA effects is similar to the situation associated with PRN 16 in Fig.'s. Amplitude fluctuations appear as clear wave forms.

The purpose of frequency domain characteristic analyses lies in precisely specifying whether or not obvious low frequency noise or periodic phenomena exist. It is possible--on the foundation of time domain autocorrelation function analyses--to go through characteristic analyses associated with power spectrum density functions and periodograms in order to obtain them.

Power spectrum density (PSD) functions are Fourier transforms of autocorrelation functions. Making use of autocorrelation function  $R_X(k)$  obtained from GPS time comparison dispersion data  $X(t)$ , it is possible to calculate power spectrum density  $S_X(f)$  to be:

$$S_X(f) = 2[R_X(0) + 2 \sum_{k=1}^{N-1} R_X(k) \cos 2\pi k f], \quad f = j/T, \quad (j=1, 2, \dots, N/2) \quad (1)$$

In this,  $N$  is the number of data sampling iterations.  $T$  is the time interval associated with finite data.  $S_X(f)$  can be calculated by FFT algorithm directly from GPS time comparison equations of time  $X(t)$ .  $S_X(f)$  calculation results make use of spectrum windows (for example, Hamming or Hann spectrum windows) to carry out smoothing in order to reduce the level of dispersion. /50

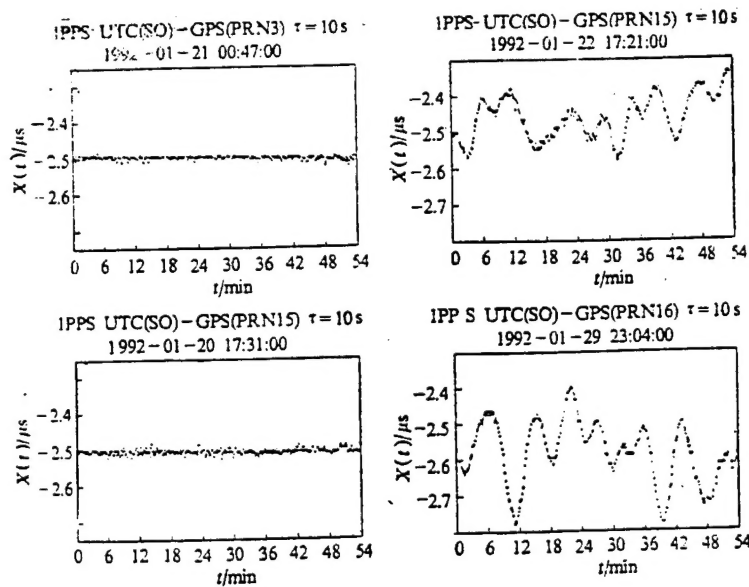


Fig.1 Time Difference Changes Associated with GPS Time Comparisons Under the Two Conditions

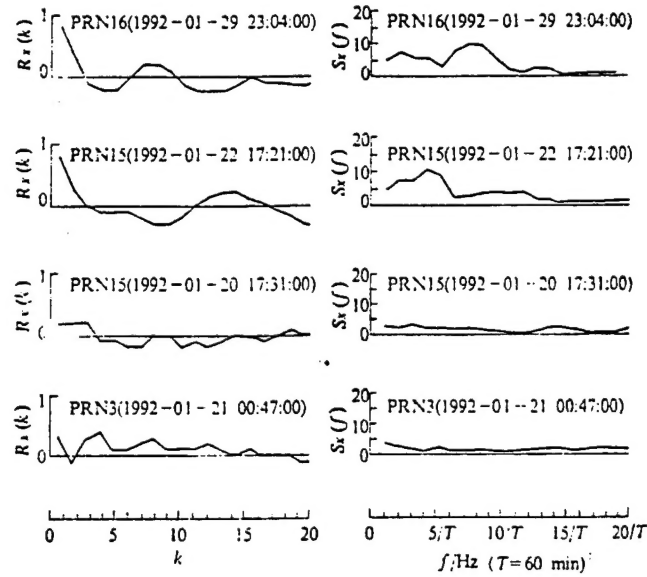


Fig.2 Correlation Diagrams and Frequency Spectrum Diagrams  
Associated with GPS Time Comparisons Under the Two Conditions  
Key: (1) Correlation Diagrams (2) Frequency Spectrum Diagrams

From the state of changes in power spectrum densities  $S_x(f)$  as a function of Fourier frequencies  $f$ , it is possible to precisely determine a number of frequency domain characteristics associated with variables  $X(t)$ : (1) If this type of change is basically level or undulates very little,  $X(t)$  is a modulated phase white noise process. (2) If the slope associated with this type of change presents an exponential attenuation,  $X(t)$  is a low frequency noise process. (3) If this type of change has clear peak values,  $X(t)$  manifests obvious periodic phenomena. If one needs to precisely specify periodic phenomena, it is possible to go through Fourier transforms to carry out periodogram analyses.

The Fourier expression associated with dispersion variable  $X(t)$  is:

$$X(t) = a_0 + \sum_{j=1}^K \left( a_j \cos \frac{2\pi j t}{N} + b_j \sin \frac{2\pi j t}{N} \right) = a_0 + \sum_{j=1}^K A_j \sin \left( \frac{2\pi j t}{N} + \theta_j \right) \quad (2)$$

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Table 1 Analysis Results for BLOCK I Satellite GPS Time Comparison  
Frequency Domain Characteristics and Time Domain  
Characteristics

接收卫星		接收日期		谱密度函	周期	自相关	⑥ 噪声过程的斜率		
		和起始时间		数特性	特性	函数特性	$\tau/s$	$\sigma_y(\tau)$	Mod $\sigma_y(\tau)$
PRN 3	1992-01-21	00:47:00	基本平坦	不明显	基本平坦	10~500	-1.006	-1.467	
PRN 6	1992-01-21	01:49:00	基本平坦	不明显	基本平坦	10~500	-0.998	-1.427	
PRN 11	1992-01-29	11:27:00	基本平坦	不明显	基本平坦	10~500	-0.995	-1.234	
PRN 12	1992-01-22	03:13:00	基本平坦	不明显	基本平坦	10~500	-1.027	-1.402	
PRN 13	1992-01-21	21:53:00	基本平坦	不明显	基本平坦	10~500	-0.987	-1.258	

Key: (1) Reception Satellite (2) Reception Date and Start Time  
(3) Spectrum Density Function Characteristics (4) Period  
Characteristics (5) Autocorrelation Function Characteristics  
(6) Noise Process Slopes (7) Basically Level (8) Not Clear  
(9) Basically Level

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In equations,

$$K = \begin{cases} N/2 & \text{when } N \text{ is even} \\ (N-1)/2 & \text{when } N \text{ is odd} \end{cases}$$

$$t = 1, 2, \dots, N; A_j = \sqrt{a_j^2 + b_j^2}; \theta_j = \arcsin(a_j/A_j)$$

By FFT methods, solve for parameters  $a_0$ ,  $a_j$ , and  $b_j$ . After that, incorporate them into amplitude  $A_j$  and phase  $\theta_j$ . Carrying out F tests on the basis of these parameters, it is possible to precisely determine whether or not certain periodic terms are obvious ( $P=1/f=T/j$ ). During inspections, obvious levels are selected as



$a=0.01$ . In conjunction with this, the previous 3 obvious periods are selected to do comparisons. /51

Table 2 Analysis Results for BLOCK II Satellite GPS Time Comparison Frequency Domain Characteristics and Time Domain Characteristics

接收卫星 (1)	接收日期和起始时间 (2)	谱密度函数特性 (3)	周期特性 (按显著顺序排列, 时间单位: min) (4)	自相关函数特性 (5)	噪声过程的斜率 (6)		
					$\tau/s$	$\sigma_y(\tau)$	Mod $\sigma_y(\tau)$
PRN 2	1992-01-20 16:07:00	低频谱较明显 (7)	8.6, 12.0, 15.0	波浪性变化 (9)	10~40	-0.539	-0.725
					50~100	0.456	0.472
PRN 14	1992-01-20 19:27:00	低频谱较明显 (7)	10.0, 8.6, 60.0	波浪性变化 (9)	10~40	-0.638	-0.812
					50~100	0.536	0.472
PRN 15	1992-01-22 17:21:00	低频谱较明显 (7)	15.0, 30.0, 12.0	波浪性变化 (9)	10~40	-0.590	-0.749
					50~100	0.477	0.443
PRN 16	1992-01-29 23:04:00	低频谱较明显 (7)	6.7, 7.5, 8.6	波浪性变化 (9)	10~40	-0.475	-0.577
					50~100	0.592	0.564
PRN 17	1992-01-20 02:11:00	低频谱较明显 (7)	20.0, 8.6, 6.7	波浪性变化 (9)	10~40	-0.457	-0.614
					50~100	0.203	0.245
PRN 18	1992-01-19 22:31:00	低频谱较明显 (7)	7.5, 6.7, 30.0	波浪性变化 (9)	10~40	-0.576	-0.735
					50~100	0.500	0.469
PRN 19	1992-01-20 13:21:00	低频谱较明显 (7)	4.6, 7.5, 10.0	波浪性变化 (9)	10~40	-0.536	-0.681
					50~100	0.332	0.315
PRN 20	1992-01-19 06:41:00	低频谱较明显 (7)	20.0, 30.0, 12.0	波浪性变化 (9)	10~40	-0.619	-0.790
					50~100	0.464	0.435
PRN 21	1992-01-19 07:44:00	低频谱较明显 (7)	12.0, 8.6, 15.0	波浪性变化 (9)	10~40	-0.492	-0.612
					50~100	0.523	0.481
PRN 23	1992-01-19 04:31:00	低频谱较明显 (7)	30.0, 12.0, 10.0	波浪性变化 (9)	10~40	-0.482	-0.587
					50~100	0.586	0.517
PRN 24	1992-01-30 18:25:00	低频谱较明显 (7)	5.4, 27.8, 17.6	波浪性变化 (9)	10~40	-0.660	-0.871
					50~100	0.213	0.216
PRN 15	1992-01-20 17:31:00	基本平坦 (8)	不明显	基本平坦 (8)	10~500	-0.980	-1.445

Key: (1) Reception Satellite (2) Reception Date and Start Time (3) Spectrum Density Function Characteristics (4) Period Characteristics (Arranged in accordance with the order of obviousness. Time unit: min) (5) Autocorrelation Function Characteristics (6) Noise Process Slope (7) Low Frequency Spectrum Relatively Clear (8) Basically Level (9) Wave Shaped Variation

Results associated with frequency domain characteristics and time domain characteristics are corresponding ones. In the Fig.'s and Tables, we take their results and set them out together to make comparisons. Fig.2 is examples of autocorrelation diagrams and frequency spectrum diagrams associated with GPS time comparisons under the two types of conditions. Table 1 and Table 2 are, respectively, analysis results for frequency domain characteristics and time domain characteristics associated with GPS time comparisons for BLOCK I satellites and BLOCK II satellites. In these two tables, time domain results have autocorrelation function characteristics and noise process slopes (drawn up in accordance with different sampling period ranges and two types of Allan variances, the majority of autocorrelation coefficients are larger than 0.9)[1,2]. As far as the explanations of these Fig.'s and tables are concerned, when sampling periods are 1 minute and satellite tracking periods are 1 hour, 1) frequency spectrum characteristics associated with GPS time comparisons for normal conditions (all BLOCK I satellites and BLOCK II satellites) are basically level. Periodic characteristics are not clear and are phase modulated white noise processes. 2) Low frequency spectra associated with GPS time comparisons influenced by SA effects (a majority of BLOCK II satellites) are relatively clear. Periodic phenomena are obvious. In the preceeding 3 obvious periods, 5-15 minute period signals account for 77%. This is nothing else than the cause for drops in precision associated with GPS time comparisons influenced by SA effects. This also explains why there are some statistical patterns associated with it.

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